

AN EXPERIMENTAL STUDY OF THE ROLE OF THE CAUDAL FIN IN THE SWIMMING PERFORMANCE OF A TROPICAL FISH, *EUCINOSTOMUS LEFROYI*

by

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ABSTRACT. - The effect of amputation of the caudal fin on swimming performance in the mojarra, *Eucinostomus lefroyi*, has been studied by measuring the oxygen consumption of tailless fish at various swimming speeds in comparison to controls with tails. At the lowest swimming speeds removal of the tail made no significant difference to the oxygen consumption. At higher swimming speeds the tailless fish used more oxygen and at the fastest swimming speeds their oxygen consumption was almost double that of the controls. These results suggest that in *Eucinostomus lefroyi* the caudal fin is important in producing thrust during sustained swimming, particularly at high speeds.

RÉSUMÉ. - L'effet produit sur la performance de nage du majarra (*Eucinostomus lefroyi*) après l'amputation de la nageoire caudale, a été étudié en comparant, pour des vitesses de nage diverses, la consommation d'oxygène de poissons sans queue à celle de poissons témoins. Pour une vitesse de nage faible, l'amputation de la queue n'a pas d'influence significative sur la consommation d'oxygène. A des vitesses plus rapides, les poissons sans queue consomment plus d'oxygène et, aux vitesses les plus grandes, leur consommation d'oxygène est presque le double de celle des poissons témoins. Ces résultats suggèrent que, chez *Eucinostomus lefroyi*, la nageoire caudale est importante dans la production de la force de propulsion pendant la nage continue, surtout à de grandes vitesses.

Key-words. - Gerreidae, *Eucinostomus lefroyi*, Oxygen consumption, Caudal fin, Swimming.

INTRODUCTION

One of the more interesting problems in the mechanics of fish locomotion is the propulsive role of the caudal fin. Theoretical considerations suggest that for fish swimming in the carangiform mode, considerable drag is associated with the lateral propulsive movements of the caudal fin to an amount equivalent to that produced by the thrust from the organ (Lighthill, 1970). Amputation of the caudal fin would therefore result in a reduction of drag as well as thrust. Apart from observations that caudal-fin amputation does not appear to seriously impair sustained swimming performance (Gray, 1968) there is only one study of the energetic consequences of caudal fin amputation. Webb (1973) showed that amputation of the caudal-fin of the sockeye salmon *Oncorhynchus nerka* had little effect on sustained swimming performance and produced no significant differences in active or standard metabolic rates. He concluded that the principal function of the caudal fin was for manoeuvrability and acceleration and, somewhat surprising, that it made little or no contribution towards net forward thrust. However, the model of Lighthill (1969, 1970) indicates that the thrust reduction produced by caudal fin amputation would be of sufficient magnitude to seriously handicap swimming performance.

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In view of the general interest in the topic, I thought that it would be worthwhile to reinvestigate the role of the caudal fin in sustained swimming performance in another species of fish and over a wider range of swimming speeds than those employed by Webb (1973).

The species chosen, the mojarra (*Eucinostomus lefroyi*) is common in the region where the experiments were performed (University of Miami, Florida), and is found in shallow coastal waters in all subtropical and tropical seas (Midgalski and Fichter, 1977). It swims in the classical carangiform mode.

MATERIALS AND METHODS

Specimens of *Eucinostomus lefroyi*, 3.9-7.5 g weight, 6.8-8.8 cm total length, were captured locally in Biscayne Bay, and held for three weeks in aerated tanks at $24.5 \pm 1^\circ\text{C}$. They were fed regularly on Purina trout chow. Two days before an experiment, a fish was selected and isolated in an aquarium where it was not fed. The night before an experimental run the fish was transferred to the respirometer in order to acclimatise it to the apparatus. The caudal peduncle of fish anaesthetized in MS 222 (0.3 g/l) was removed with a scalpel (Fig. 1). The fish were allowed to recover for 5 days, and fish that appeared healthy were used for oxygen consumption measurement.

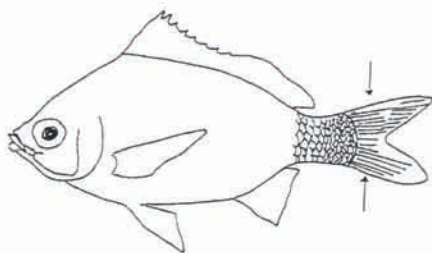


Fig. 1. - Place of amputation of the caudal fin (arrows).

Oxygen consumption was measured using a modified Brett (1964) type respirometer. Fish swam in the tunnel at 5, 15, 25 and 35 cm/sec for 35 min. at each swimming speed. A 62-W submersible pump driving an impeller at the rear of the chamber was capable of generating current of up to 50 cm/sec in the swimming portion of the respirometer. At the end of each run the fish was removed from the chamber and a blank reading recorded. Measurements of the fish total length, depth and width were taken into account to correct for the solid blocking effect of the fish on the speed of the water flowing over its body (Webb, 1975). During each run, oxygen consumption was estimated from the fall in oxygen tension measured by oxygen electrode, recorded on a chart recorder (oxygen saturation was never allowed to drop to less than 70%).

RESULTS

For all animals oxygen consumption increased in a curvilinear manner up to swimming speeds of 35 cm/sec (Fig. 2). On reducing the swimming speed to minimal activity (5 cm/sec) one hour. This indicates that little oxygen debt was incurred in these experiments and that the swimming speeds were within the aerobic scope of this species.

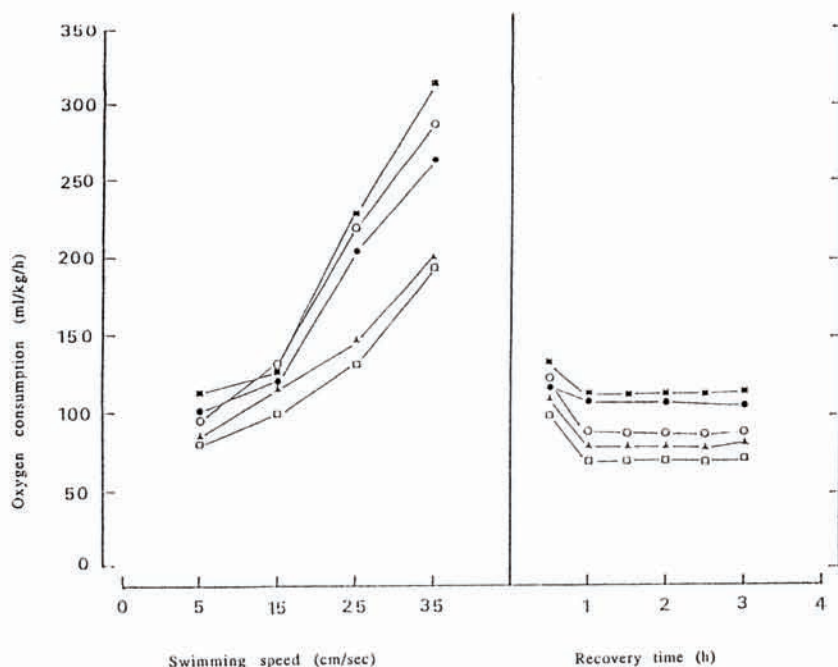


Fig. 2. - Oxygen consumption rates versus swimming speed and time following exercise for five representatives, *Eucinostomus lefroyi*.

For the unamputated (control) fish a plot of oxygen consumption versus swimming speed yielded a highly significant linear relationship for all individuals (Fig. 3a).

$$VO_2 = 101.9 \pm 2.46 S$$

where VO_2 = oxygen consumption, expressed in ml/kg/hr; S = speed, in cm/sec; $R = 0.92$.

Extrapolating slopes for individual fishes to 0 speed gave a mean standard metabolic rate of 103.8 ± 4.2 ml O_2 /kg/hr ($n = 5$).

Tailless fish also showed a significant relationship between O_2 consumption and speeds, although the data are much more scattered compared to the control fishes (Fig. 3b).

$$VO_2 = 117.0 \pm 6.215 \quad R = 0.68$$

The resting oxygen consumption for these animals was 117 ± 20.1 ml O_2 /kg/hr ($n = 5$), which was not significantly different from whole animal controls. However, the slope of the curve is much steeper and at 35 cm/sec, the tailless fish have almost twice the O_2 consumption compared to the controls (control, 186.8 ± 5.1 ml O_2 /kg/hr; tailless, 346 ± 64.3 ml O_2 /kg/hr; $p = 0.05$).

DISCUSSION

The standard oxygen consumption for the control non amputated fish is within the range of that found for other fish at similar temperatures (pumpkinseed *Lepomis gibbosus*, 20.5°C, 63 ml O_2 /kg/hr, Brett, 1965; largemouth bass *Micropterus salmoides* 20°C, 156

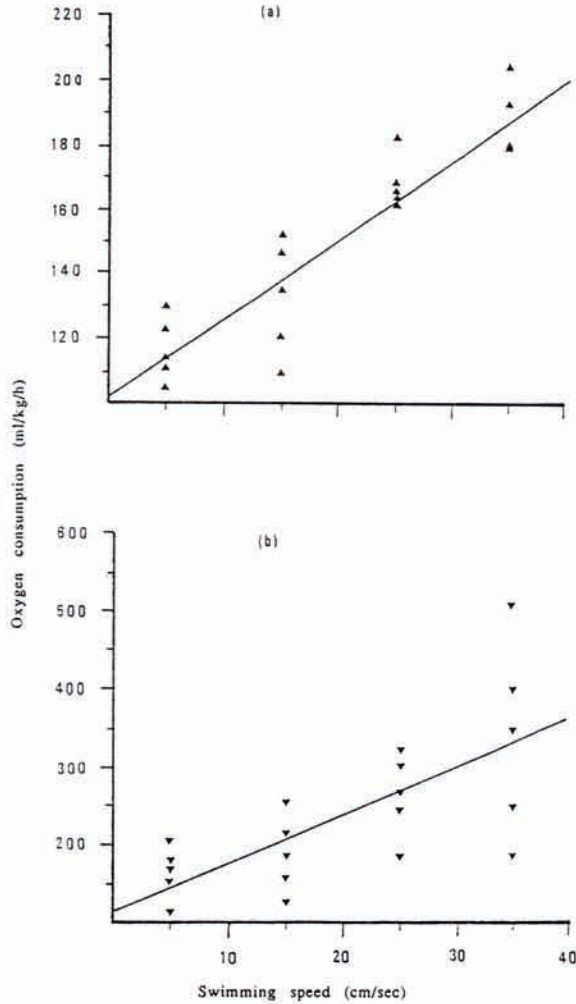


Fig. 3. - Oxygen consumption at versus swimming speed in tailed (a) and amputated (b) *Eucinostomus lefroyi*.

ml O_2 /kg/hr, Beamish, 1970; and tilapia *Tilapia nilotica*, 25°C, 145.6 ml O_2 /kg/hr, Febry and Lutz, 1987). The maximal sustained oxygen consumption (553 ml O_2 /kg/hr) is similar to the active metabolic rate for *Lepomis gibbosus* (571 ml O_2 /kg/hr, Brett, 1965), but considerably less than the maximal oxygen consumption recorded for the sockeye salmon acclimated to 20°C (1.265 ml O_2 /kg/hr, Brett, 1964). The slope of $\log VO_2$ /speed (0.0072) is very similar to that found for *Micropterus salmoides* over the temperature range of 10 to 34°C by Beamish (1970) (0.0085), and slightly less than that found for *Oncorhynchus nerka* by Webb (1973) (0.014).

At the lowest swimming speeds the results are in agreement to those of Webb (1975), i.e. no differences in oxygen consumption were found between fish with caudal fins and those without. However, at higher swimming speeds the increase in oxygen consumption rates was greater in the tailless fish, and at the fastest speed (35 cm) the

oxygen consumption of the tailless fish was twice that of the controls. The slope of the power performance curve ($\text{VO}_2/\text{swimming speed}$) is in consequence higher for the tailless fish indicating that the caudal fin does indeed contribute in a positive way to the efficiency (metabolic cost) of sustained swimming, the greater the speed the more important the contribution.

One reason for the difference may be that in Webb's study (1975) *Oncorhynchus nerka* swam at a much slower relative speed than *Eucinostomus lefroyi* (2.5-3.0 l/sec, *O. nerka*; 5 l/sec, *E. lefroyi*), and it is possible that, owing to data scatter, differences would only become statistically significant at higher speeds where the slopes diverged maximally. But interestingly, Webb (1973) reported a significant reduction in the critical swimming speed of the amputated salmon and an increase in the active metabolic rate, although the latter was not statistically significant.

In conclusion, it is suggested that although the caudal fin undoubtedly has a primary function in producing immediate acceleration and rapid manoeuvrability it is also important in producing thrust during sustained swimming particularly at high speeds.

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